Ilmu Pertanian (Agricultural Science)
http://journal.ugm.ac.id/jip
Vol. 7 No. 3 December, 2022: 140–151 | DOI: doi.org/10.22146/ipas.71494

Effects of nano zeolite-coated fertilizer and cow bone on the growth and N uptake of maize in inceptisol of Patuk, Gunung Kidul

Khairul Anwar*, Sri Nuryani Hidayah Utami, and Makruf Nurudin

Department of Soil Science, Faculty of Agriculture, Universitas Gadjah Mada
Jln. Flora no. 1, Bulaksumur, Sleman, Yogyakarta 55281, Indonesia
*Corresponding author: khairulanwara07@gmail.com

Article Info

Received : 23rd December 2021
Revised : 19th May 2022
Accepted: 20th June 2022

Keywords:
Inceptisols, maize, cow bone, zeolite, nano-techno fertilizer

Abstract

Nanotechnology is a science that deals with objects measuring 1–100 nm that are different from their original properties. Nano-technology fertilizers are more reactive and on target with minimum use. Nanotechnology fertilizers can be utilized as slow-release fertilizers, allowing for optimum fertilizer uptake by plants. Because of the holes that can store nitrogen fertilizers, zeolite and bovine bone can be utilized as fertilizer coatings. This study was conducted at Universitas Gadjah Mada's Faculty of Agriculture. The research method used was a 2X5 factorial *completely randomized design* (CRD) with each treatment being repeated 3 times so that the total polybags used were 30 polybags. The first factor was the type of coating material for urea, nano zeolite, and nano bovine bone. The second factor consisted of a dose of coated urea fertilizer with five kinds of dose treatments, which were 0, 100, 200, 300, and 400 kg.ha^{-1}. ANOVA was used to analyze parameter data, followed by testing using the DMRT (*Duncan's Multiple Range Test*). When compared to nano bovine bone, the effectiveness of N removal with nano zeolite generated the best results as a slow-release fertilizer on N uptake. The best N fertilization dose with nano zeolite coating was 200 kg.ha^{-1}, which increased corn plant growth by producing the highest plant height (167.17 cm) and N uptake of 1.6 g/plant. This research can be a recommendation for more effective and efficient Nitrogen fertilization for corn farmers.

INTRODUCTION

Nitrogen (N) is so critical for plant growth and development that this ingredient is required in high amount (Hanafiah et al., 2010). According to Lingga and Marsono (2008), the typical nature of N fertilizers is quickly lost, so that N should be supplied gradually to reduce the loss of N due to washing and evaporation. N is required for the growth of vegetative components such as leaves, stems, and roots in maize. Loss of N nutrient from the soil in the form of gas (N_2, N_2O, NO, and NH_3) occurs as a result of leaching and harvesting, while in the gaseous form, N is lost in the denitrification reaction and volatilization of ammonium (Damanik et al., 2010). The majority of N loss could occur by leaching (44%), and the remaining occurs through volatilization and denitrification, rendering fertilization inefficient.

In mainland Indonesia, inceptisols are found in the greatest number (about 70.52 million ha, or 37.5%). This type of soil can be found anywhere from coastal plains to hilly and mountainous terrain. For agricultural land, most farmers use inceptisols. As inceptisols are undeveloped soils that have not undergone extensive leaching, their fertility is relatively low due to weathering and leaching influenced by the wet and dry seasons, causing nutrients to be easily lost. According to Pakpahan et al. (2018), the challenges faced by inceptisols include low nutrient content, particularly nitrogen, phosphorus, and potassium nutrients, which means that additional nutrients must be provided, for example, through

How to cite: Anwar, K., Utami, S.N.H. and Nurudin, M. (2022). Effects of nano zeolite-coated fertilizer and cow bone on the growth and N uptake of maize in inceptisol of Patuk Gunung Kidul. *Ilmu Pertanian (Agricultural Science)*, 7(3), pp. 140–151.

ISSN 0126-4214 (print) ISSN 2527-7162 (online)

fertilization, to carry out cultivation in these soils. Inceptisols feature a rather deep solum, about 1–2 meters thick; black or gray to dark brown color; sand, silt, and clay texture; crumb soil structure; loose consistency; pH 5–7; organic matter (10–31%); and moderate to high nutrient content (Utami et al., 2003). According to Setyastika and Suntari (2019), inceptisols have the potential for agricultural and plantation crops such as rice, corn, and beans, as well as for horticulture. Using zeolite and bovine bone as a N nutrient coating is one of the most effective ways to give and retain N nutrient in inceptisols.

The use of zeolites and beef bones is one of the methods to reduce N leaching, volatilization, and denitrification, hence maintaining and increasing N availability in inceptisol soils. Zeolite is a hollow silicate mineral with a high Cation Exchange Capacity (KPK) (80–108 cmol(+)/kg), which means it can exchange cations with other cations. Zeolites are negatively charged, have three-dimensional structural features, and are pores packed with ions of K, Na, Ca, Mg, and H_2O molecules to allow ion exchange and water release back and forth (Juarsah, 2016). Pratomo et al. (2009) claimed that zeolite can be employed as a supporting material for slow-release substances by exploiting the zeolite's surface area and adsorption capacity. According to the findings of Aina et al. (2017), zeolite was employed as a zeolite-coated urea coating with a concentration of 10% and produced the best cob weight and cob length output in corn plant testing. Bovine bones can also be utilized in the production of slow-release fertilizers due to 93% hydroxyapatite ($Ca_{10}(PO_4)6(OH)2$) and 7% β-*tricalcium phosphate* ($Ca_3(PO_4)2$,β-TCP) content (Ooi et al., 2007). According to Kubo et al. (2003), hydroxyapatite is bioceramic with a porous surface structure that can bind nitrogen. One of the technologies that can increase the effectiveness and efficiency of zeolite and bovine bone as a coating material for N fertilizer is nanotechnology (Ariningsih, 2016).

Nanotechnology is a branch of science that deals with objects measuring 1–100 nm in size that have different qualities from the original material and the capacity to control or alter on an atomic scale (Mujahid et al., 2017). Materials on the nanoscale size (10^{-9}m) have better characteristics and performance than those on the micrometer scale (10^{-6} m) (Thirunavukkarasu, 2015). Widowati et al. (2011) claimed that very small nano fertilizers (1 nm=10^{-9} μm) have more reactive qualities and can directly hit the target where their use is only required in small quantities. Fitriatin et al. (2018) explained that nano-sized particles are more reactive and effective than larger particles at the same dose. Furthermore, to improve the effectiveness and efficiency of N fertilizer, the fertilizer should be converted into a slow-release fertilizer, in which the nutrients contained in the fertilizer are released gradually based on when it is required by the plant. According to Savana and Dina (2017), slow-release fertilizer may manage the rate of release of nutrient elements that are readily lost due to solubility in water, evaporation, and the fertilizer's denitrification process. According to Subramanian et al. (2015), the release of nutrients is related to the particle size of the coating, where particles measuring 30–40 nm can hold a lot of nutrient ions because they have a high surface area. The use of nano zeolite and nano bovine bone as a slow-release fertilizer for N nutrients will improve the chemical properties of inceptisols because it reduces evaporation in the form of ammonia, denitrification, erosion, and leaching so that the availability of N nutrients will be fulfilled.

This study aimed to determine the effectiveness of N coating with nano zeolite and bovine bone as a slow-release fertilizer on inceptisols N uptake and determine the optimum N dose with nano zeolite and bovine bone in increasing the growth and N uptake of corn on inceptisols.

MATERIALS AND METHODS

This research was conducted in March–July 2021 at the Soil Laboratory, Research Laboratory, Green House, Universitas Gadjah Mada. The materials used in this study were Pioneer Hybrid 21 corn seed, KCL, Urea, SP-36, beef bone, zeolite, and inceptisols. The tools used in this study were a hoe, shovel, scale, ruler, bottle, bucket, spray, steel, ball mill, label and plastic, oven, and measuring cup. The research applied a factorial 2X5 *Completely Randomized Design* (CRD) method, each treatment was repeated 3 times so that the total polybags were 30 polybags. The first factor was the type of coating material for urea, nano zeolite, and nano cow bone. The second factor was the dose of coated urea fertilizer with five kinds of dose treatment, which were 0, 100, 200, 300, and 400 kg. ha^{-1}. Parameter of data analysis used ANOVA proceeded with the following test using the DMRT test (*Duncan's Multiple Range Test*). The following research design is presented in Table 1.

Manufacture of fertilizer was carried out by making

Table 1. Method of nano zeolite (KI) and nano cow bone (Q1)

Dosage of fertilizer N		Coating type	
		Nano zeolit	Cow bone nano
Dosage	0	K1R1 (R0)	Q1R1 (R0)
	100	K1R1 (R1)	Q1R1 (R1)
	200	K1R1 (R2)	Q1R1 (R2)
	300	K1R1 (R3)	Q1R1 (R3)
	400	K1R1 (R4)	Q1R1 (R4)

Table 2. Physical and chemical properties of inceptisols

No.	Parameters	Unit	Inceptisols	Level
1	pH			
	pH H_2O	-	5.7	Slightly acidic
	pH KCl	-	5.1	Extremely acidic
2	Organic C	%	1.2	Low
3	Organic matter	%	2.1	-
4	CEC	cmol(+)kg^{-1}	18.4	Moderate
	Ca	cmol(+)kg^{-1}	0.6	Extremely low
	Mg	cmol(+)kg^{-1}	1.1	Moderate
	K	cmol(+)kg^{-1}	0.2	Low
	Na	cmol(+)kg^{-1}	0.02	Extremely Low
5	Total N	%	0.2	Low
6	Available N			
	NH_4^+	µg/g	260.6	-
	NO_3^-	µg/g	410.9	-
7	Available P	mgkg^{-1}	2.21	Low
8	Bulk Density BD)	g.cm^{-3}	1.1	
9	Specific Weight (SW)	g.cm^{-3}	2.2	
10	Porosity	%	52	
11	Texture			
	Sand	%	35	
	Silt	%	53	Silty clay
	Clay	%	9	

Remarks: Categories based on Balai Penelitian Tanah (2009).

zeolite and cow bone into a nano size using mill, with a ratio of steel ball, zeolite/cow bone, and water respectively 500 g : 100 g : 60 ml. The milling process was done for 6 hours (Nainggolan et al., 2009) The formulation was carried out by mixing urea with nano zeolite and nano bovine bone according to the treatment in a ratio of 6:1 (Kottegede et al., 2017). Mixing is done conventionally using centrifugal force. The basic fertilization was carried out 7 days before planting 100 kg/ha of SP-36 and 100 kg/ha of KCl. Nano fertilizer was given 7 days after planting the parameters observed. The characterization of nanoparticles used *Scanning Electron Microscopy* (SEM) (Manikandan et al., 2014) and analysis using J-image. The plant parameters observed included plant height, number of leaves, fresh weight of roots and shoots, dry weight of roots and shoots, and N uptake of maize plants.

RESULTS AND DISCUSSION

The data of initial soil properties before treatment are presented in Table 2. The actual pH value of inceptisols in this study was 5.7, which is classified acidic (Balittanah, 2009). Inceptisols has an acidic pH, high clay content, and the surface layer which is easily washed so nutrients can easily lose (Sudirja et al., 2017). The organic C content in this soil was 1.26%, which is classified low according to Balittanah (2009) and when converted, the value of organic matter was 2.17%. The low organic matter content is caused by the young and underdeveloped inceptisols that has not undergone intensive leaching. Constraints possessed by inceptisols include low organic C-content and nutrients, especially nitrogen, phosphorus, and potassium nutrients, so that to carry out cultivation in these soils, additional nutrients must be provided, for example through fertilization (Pakpahan et al., 2018). Organic matter can contribute to an increase in negative charge (Darlita et al., 2017). The ability of the soil to exchange cations (CEC) in this study was 18.35 cmol(+1).kg^{-1}, which according to Balittanah (2009) is classified moderate. Soil CEC is affected by soil pH, organic matter content, types of clay minerals, and soil texture. Meanwhile, the available soil elements (Ca, Mg, K, and Na) and base saturation are classified extremely low and moderate, respectively. Soil CEC is related to cations in the soil so when the soil CEC is low, the cations such as Ca, Mg, and Na absorbed by plants are also low (Gunawan et al., 2019). Based on the analysis results, the total nitrogen content of inceptisols was 0.23%, and the nitrogen content available both in the form of ammonium (NH_4^+) and nitrate (NO_3^-) was 260.62 mg/kg and was 410.98 mg/kg, respectively. The total N value is classified low due to the low organic matter in the soil (Balittanah, 2009). Sonbai et al. (2019) mentioned that organic matter can increase the availability of nitrogen in the soil. The available P in this study was 2.21 g.g^{-1}, classified as low according to the Balittanah (2009). The low available P of the soil is related to the high Al oxalate extracted, because in most soils, the oxides, hydroxides, and oxidases of Al and Fe are the most dominant components in fixing P. Inceptisols have a slightly acidic pH and have a high clay content which causes P to be fixed by Al, Fe, or Mn, making it unavailable (Adviany and Maulana, 2019). Inceptisols in this study had a bulk density of 1.1 g.cm^{-1}. The bulk density values of mineral soils range from 1.0 to 1.3 g.cm^{-3} for fine-textured soils. The specific gravity value obtained in the initial soil analysis was 2.2 g.cm^{-3}. Specific gravity (BJ) of soil is the weight (g.cm^{-3}) of the soil solid fraction without the presence of pores where the BJ value obtained from the results of the initial soil analysis was 2.2 g.cm^{-3}. In general, the value of specific gravity is not too varied, which is around 2.65 g.cm^{-3}. However, specific weight may have varying values, depending on the mineral composition of the soil (Balittanah, 2009). Soil porosity is the percentage of soil volume that is not occupied by the solid part of the soil. Calculation of the ratio of BD and SW of soil is usually used to calculate the value of soil porosity. The total number of pore spaces in the soil mass is called the total pore space (n), which was 51.64%. The values of soil porosity depend on several factors, including bulk density, the extent of particle size distribution, particle shape, and cementation material (Nimmo, 2005). The percentage of soil texture in this study consisted of 35% sand, 53% silt, and 9% clay, which is in the silty clay category according to the USDA texture triangle.

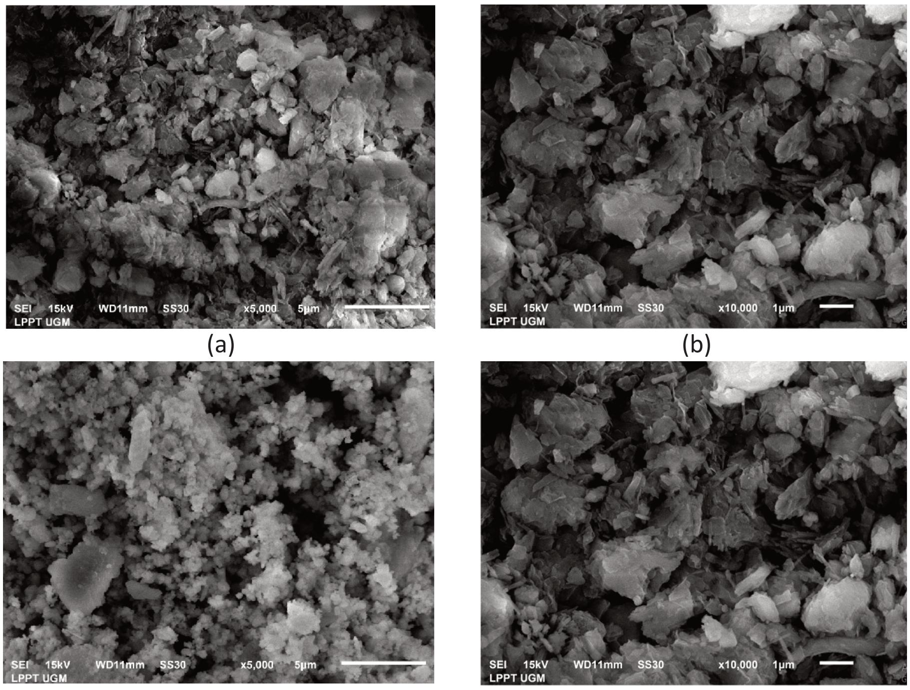
Characteristics of nano-tech fertilizer

Based on Table 3, the SEM results of nano zeolite and cow bone at magnifications of 5000× and 10,000× showed grains which indicated that the particles were split into smaller sizes (Figure 1). Zeolite was split into smaller particles, such as 34.51% measuring 1–10 nm, 25.61% measuring 10–20 nm, 32.11% measuring 20–100, 7.21% measuring 250–1000 nm, and 0.12% measuring >1000 nm (Table 3). The average size of the zeolite formed was 37.77 nm. Meanwhile, the nano size of cow bone formed was 1–20 nm (0%), 10–20 nm (0%), 20–100 nm (87%), 100–250 nm (13%), 250–1000 nm (0%), and >1000 nm (0%). The average size of the cow bone formed was 62.32 nm. The manufacture of nanomaterials is said to be successful if 50% or more of the particles produced are 1–100 nm in size (Khan et al., 2019). The total zeolite with a size of 1–100 nm was 91.41%, and the nano cow bone with a size of 1–100 nm was 87%, indicating that the manufacture of nanomaterials was declared successful. The splitting of the particles into nano size was thought to be caused by the collision between the particles and the steel ball for 6 hours. The synthesis of nanoparticles using a

Table 3. Particle size of nano zeolite (KI) and nano cow bone (Q1)

No	Diameter	Nano zeolite	%	Nano cow bone	%
		Total		Total	
1	1-10	1556	34	0	0
2	10-20	1321	25	0	0
3	20-100	1497	32	480	87
4	100-250	320	7	60	13
5	250-1000	121	2	0	0
6	>1000	0	0	0	0
		Mean = 37.7 nm		Mean = 62.3 nm	

Remarks: The result of testing using Image-J software.



(a) (b) (c) (d)

Figure 1. The results of SEM analysis of nano zeolite rocks with (a) 5,000× magnification and (b) 10,000× magnification, nano cow bone with (c) 5,000× magnification and (d) 10,000× magnification

Table 4. Chemical properties of nano zeolite (KI) and nano cow bone (Q1)

No.	Partikel nano	Nano zeolit (%)	Nano cow bone (%)
1	O	64.6	28.0
2	Na	0.7	0.7
3	Mg	0.4	0.6
4	Al	4.9	0.1
5	Si	24.0	0.3
6	K	0.5	-
7	Ca	1.9	45.9
8	Cu	-	1.6

physical approach, especially milling using high-energy ball milling, can make nanoparticles (Subramanian et al., 2015). In the High Energy Ball Milling Process, Mechanical Alloying occurs, which is a technique that includes repetition, joining, crushing, and recombining for powder grains. The particle size of zeolite was reduced to 1,078, 475, 398, 357, and 203 nm after milling for 0, 1, 2, 4, and 6 hours with a ball mill. The change in particle size also increased the surface area of 41, 55, 72, 83, and 110 $m^2 g^{-1}$, respectively.

Zeolites that have undergone a change in size to nano can increase the efficiency and effectiveness of fertilization on plants because they are able to release nutrients slowly, thereby reducing fertilizer doses (Lateef et al., 2016). The highest element content in nano zeolite was O and Si, amounting to 64.6% and 24.05%, while the lowest content was Mg, which was 0.37%. Table 4 shows that the Si element, which is marked with blue dots, almost fills the entire surface compared to the Mg element marker dots. Zeolite is a microporous aluminosilicate crystal with various elements containing the intrinsic properties of strong acidity, high surface area, high thermal stability, and shape selectivity. This is in line with the research results of Ginting et al. (2013), showing that the highest element content in zeolite taken from various places was Si, which was 91.55, 76.29, and 67.28. The results of Estiaty et al. (2015) showed that the main composition of zeolite was dominated by Si (72.3%) and Al (10.68%). The highest element content in nano cow bone was O and Ca, amounting to 28.06 and 45.95%, while the lowest element content was Al, amounting to 0.15%. The content of Ca, which is marked with yellow dots, fills all surfaces compared to the points of Al element markers. According to Haris (2016) cow bone contained 7.07% $CaCO_3$, 1.96% CaF_2, 2.09 P, and 58.305% $Ca_3(PO_4)_2$. The composition of cow bone is mostly dominated by calcium and phosphate compounds, with hydroxylapatite as the main mineral component.

N total corn plant tissue

Based on Table 5, the analysis of variance carried out on N total tissue shows a significant difference in the results between treatments. Each treatment administered gave different results and responses to the total N of maize plant tissue. The highest total N content of corn plant tissue was found at a dose of 200 kg.ha^{-1} with nano zeolite treatment. The lowest nitrogen content was obtained in the control treatment of cow bone ash nano treatment of 1.8%. Nitrogen was absorbed by plants in NO_3^- and NH_4^+ from the soil, where the average nitrogen content in plant tissues was 2%–4% dry weight. According to Polat et al. (2004) zeolites are applied to the soil, because zeolites have a high nutrient absorption capacity, especially Potassium (K) and Ammonium (NH_4^+), and the ability of the soil to bind these elements can increase. In this process, Ammonium (NH_4^+) will be temporarily trapped in the pores of the zeolite and then slowly released to be taken up by plant roots. Therefore, zeolite plays a role in retaining cations (NH_4^+) until the plants need it.

Uptake efficiency of corn plants

Based on Table 6, the analysis of variance that has been carried out on the efficiency of N uptake shows that the results are significantly different between treatments. Each treatment administered gave different results and responses to the efficiency of N uptake of corn plants. The highest results were obtained in the treatment with a dose of 200 kg.ha^{-1} nano zeolite with an average of 38%, while the lowest ones were obtained in the control treatment of nano cow bone ash with an average of 20%. Modification of zeolite dimensions to 30–40 nm is then added with nutrients (fertilizer), where N that can be adsorbed on the zeolite is able to release nutrients more slowly. The release of Nitrogen can be released for 50 days, compared to conventional urea (without nanocomponents) which is already lost in 10–12 days. The research results of (Subramanian and Tarafdar, 2011) by means of nanotechnology in trials using corn plants resulted in uptake of N from nano fertilizers was 82% more effectively than the use of conventional urea which was only 42%. This is because urea fertilizer coated with nanoparticles has a better absorption efficiency.

Table 5. Effect of dose and nanomaterials on total N content of canopy (%)

Dosage of fertilizer N	Coating type		Average
	Nano zeolit (K1)	Cow bone nano (Q1)	
0 kg (R1)	2.3	1.8	2.1 c
100 kg (R2)	3.0	2.6	2.8 b
200 kg (R3)	4.0	3.5	3.8 a
300 kg (R4)	3.7	3.5	3.6 a
400 kg (R5)	3.7	3.4	3.6 a
Average	3.3 a	3.0 b	(-)

Remarks: Numbers followed by the same letters indicate that there is no significant difference between treatments at the level α=5%.

Table 6. Effect of dose and nanomaterials on absorption efficiency levels (%)

Dosage of fertilizer N	Coating type		Average
	Nano zeolit (K1)	Cow bone nano (Q1)	
0 kg (R1)	0.00 f	0.00 f	0.00
100 kg (R2)	49 b	21 e	35
200 kg (R3)	63 a	38 cd	50
300 kg (R4)	44 bc	24 e	34
400 kg (R5)	34 d	18 e	26
Average	38	20	(+)

Remarks: Numbers followed by the same letters indicate that there is no significant difference between treatments at the level α=5%.

Table 7. Effect of dose and nanomaterials on uptake N (g)

Dosage of fertilizer N	Coating type		Average
	Nano zeolit (K1)	Cow bone nano (Q1)	
0 kg (R1)	0.2 e	0.1 e	0.1
100 kg (R2)	0.5 d	0.2 e	0.3
200 kg (R3)	1.6 a	0.8 c	1.2
300 kg (R4)	1.3 b	0.7 c	1.0
400 kg (R5)	1.3 b	0.7 c	1.0
Average	1.0	0.5	(+)

Remarks: Numbers followed by the same letters indicate that there is no significant difference between treatments at the level α=5%.

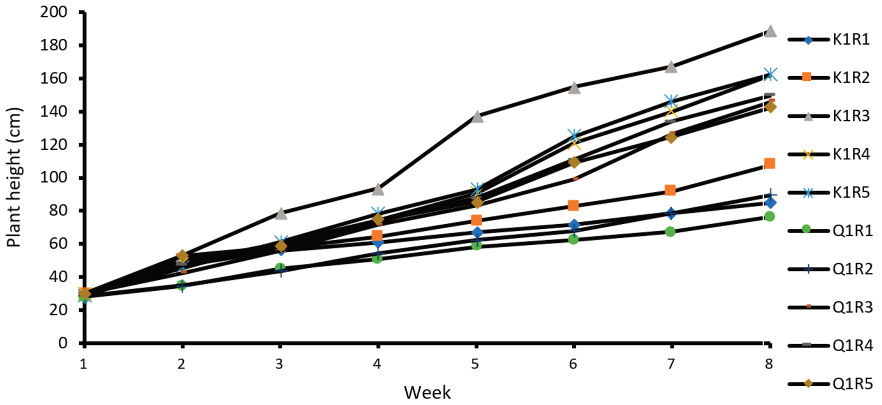


Figure 2. Corn plant height for 8 weeks

Remarks: Nano zeolite (K1RI (0 kg.ha^{-1}), K1R2 (100 kg.ha^{-1}), K1R3 (200 kg.ha^{-1}), K1R4 (300 kg.ha^{-1}), K1R4 (400 kg.ha^{-1})) and nano cow bone (Q1R1 (0 kg.ha^{-1}), Q1R2 (100 kg.ha^{-1}), Q1R3 (200 kg.ha^{-1}), Q1R4 (300 kg.ha^{-1}), Q1R4 (400 kg.ha^{-1})).

According to Widowati et al. (2011) very small nano fertilizer (1nm=10^{-9} m) has a more reactive nature that can directly hit the target, and its use is only needed in small quantities. The more nutrients that plants can absorb, the more optimal the plant's ability to grow and develop (Bhaskoro et al., 2015).

N uptake of maize plant tissues

Based on Table 7, each treatment administered gave different results of the N uptake. The highest result was obtained at the treatment of 200 kg.ha^{-1} nano zeolite (1,6%). Meanwhile, the lowest result was obtained in the control treatment of nano cow bone (0,1%) because the dry weight of shoots in this treatment was the highest compared to other treatments. In addition, the average tissue N content was also not significantly different from that in the treatment of 200 kg.ha^{-1} nano zeolite. On the other hand, there is a modification of fertilizer into nanoparticles, becoming a slow-release fertilizer. States with slow-release fertilizer is a mechanism for releasing nutrients slowly, following the pattern of nutrient absorption by plants, thereby resulting in the optimum fertilizer absorption by plant (Rugayah et al., 2019).

Plant height

Based on Figure 2, N coating with nano zeolite and cow bone resulted in a linear increase in plant height every week. Measurement of plant height was carried out until the maximum vegetative phase, which was from the age of 7 days to 56 days after planting. The maximum vegetative phase in maize plants was at the age of 8 weeks after planting. Nano zeolite coating at a dose of 200 kg. ha^{-1} showed a higher average in plant height compared to other treatments until the age of 8 weeks after planting. This is because nano zeolite has cavities that match the size of the ammonium ion so that the zeolite has a high adsorption capacity for ammonium, which is then slowly released to be taken up by plant roots. Therefore, zeolite plays a role in retaining cations (NH_4^+) until the time plants require it. Zeolite is used as a coating material because of its high cation exchange properties (Dubey and Mailapalli, 2019). Zeolites that have undergone a change in size to nano can increase the efficiency and effectiveness of fertilization on plants due to their ability to release nutrients slowly, thereby reducing fertilizer doses (Lateef et al., 2016).

Number of leaves

The number of leaves was observed every week, starting from one week to eight weeks after planting, to determine the growing rate of maize plants. Based on Figure 3, the number of leaves of maize plants increased every week until the 6th week. In that week, the number of leaves started to decrease due to the leaf senescence. Maize plants lost 4–5 leaves due to aging when they had produced 10–12 leaves (Franklin et al., 2008). Aging in individual plants begins at the basal (older) and then leaves and continues upwards. However, the decrease in the number of leaves in this study was not significant. Plant growth is related to the supply of nutrients and water. Plant growth, particularly the number of leaves, will benefit from a sufficient supply of nutrients and water. In line with the plant height, nano zeolite resulted in the highest number of leaves. This result takes place because nano zeolite can increase fertilization efficiency, providing slow-release P and K nutrients to be utilized by plants efficiently. It was reported that the formulation of urea and zeolite coated with chitosan had been able to regulate nitrogen solubility, resulting in increased fertilization efficiency and reduced fertilizer leaching (Hartatik et al., 2020).

Shoot fresh and dry weight

The fresh weight and dry weight of shoots are some of the parameters that indicate the growth of a plant. Shoot fresh weight is the shoot weight after harvest before being dried, while shoot dry weight

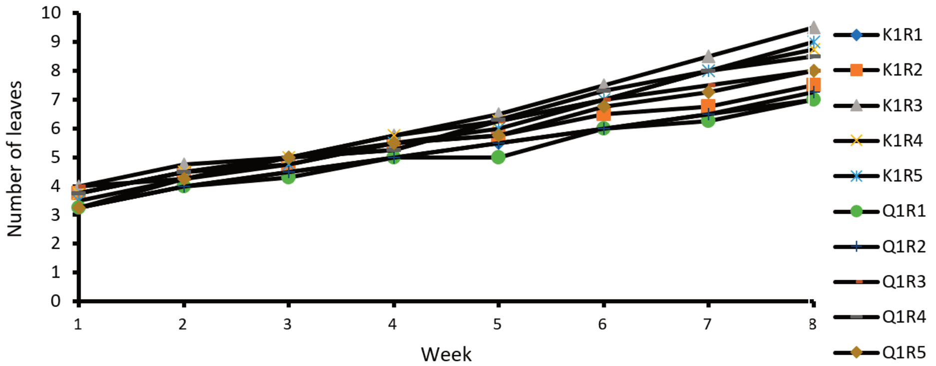


Figure 3. Number of corn plant leaves for 8 weeks

Remarks: Nano zeolite (K1RI (0 kg.ha⁻¹), K1R2 (100 kg.ha⁻¹), K1R3 (200 kg.ha⁻¹), K1R4 (300 kg.ha⁻¹), K1R4 (400 kg.ha⁻¹)) and nano cow bone (Q1R1 (0 kg.ha⁻¹), Q1R2 (100 kg.ha⁻¹), Q1R3 (200 kg.ha⁻¹), Q1R4 (300 kg.ha⁻¹), Q1R4 (400 kg.ha⁻¹)).

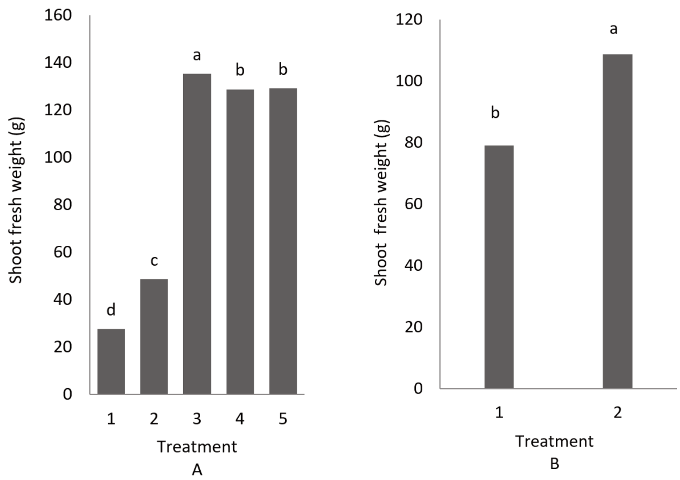


Figure 4. Shoot fresh weight corn plan

Remarks: A = 1 (control), 2 (100 kg.ha⁻¹), 3 (200 kg.ha⁻¹), 4 (300 kg.ha⁻¹), 5 (400 kg.ha⁻¹) and B =1 (nano cow bone) and 2 (nano zeolit).

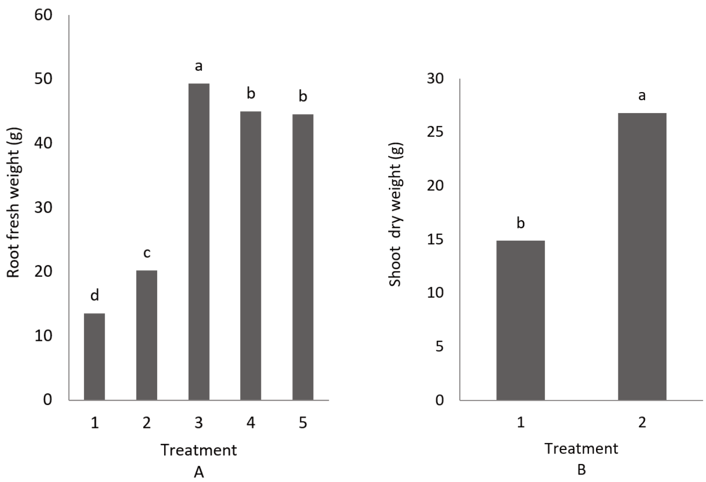


Figure 5. Shoot dry weight corn plan
Remarks: A = 1 (control), 2 (100 kg.ha^{-1}), 3 (200 kg.ha^{-1}), 4 (300 kg.ha^{-1}), 5 (400 kg.ha^{-1}) and B =1 (nano cow bone) and 2 (nano zeolit).

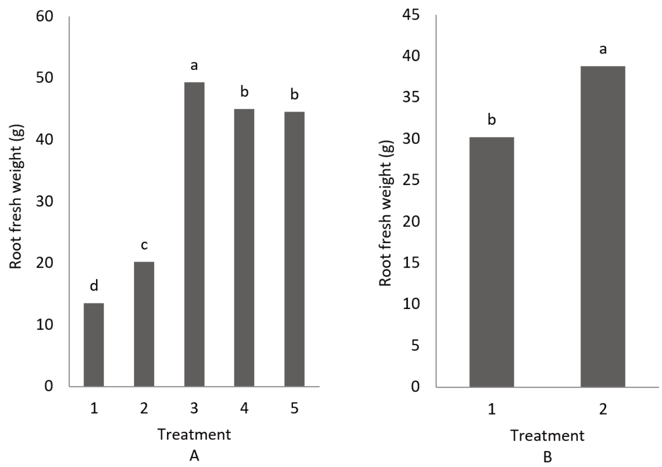


Figure 6. Root fresh weight corn plan
Remarks: A = 1 (control), 2 (100 kg.ha^{-1}), 3 (200 kg.ha^{-1}), 4 (300 kg.ha^{-1}), 5 (400 kg.ha^{-1}) and B =1 (nano cow bone) and 2 (nano zeolit).

is the shoot weight that has been dried and lost its moisture content. The treatment of 200 kg nano zeolite had a higher average fresh weight, which was 158g (Figure 4). This shows that a 200 kg nano zeolite can improve plant growth. Meanwhile, the treatment of 0 and 100 kg nano zeolite and cow bone had lower values compared to other treatments. The shoot dry weight was directly proportional to the shoot fresh weight, in which 200 kg nano zeolite resulted in the highest value of 39.2g, which was not significantly different compared to that in the treatment at the doses of 300 kg and 400 kg. The fresh weight of the plant consists of 80–90% of water, and the rest is photosynthate indicated in dry weight. Fresh weight refers to the accumulation of material produced during growth. Dry weight refers to the accumulation of net yield from CO_2 assimilation over the growing season, as the accumulation of organic compounds was successfully synthesized by plants from inorganic compounds, particularly water and CO_2. Plants provided with adequate nutrient supply will have high dry weight and yields because the nutrients available in the soil greatly affect crop yields. Nutrients that are very influential are on root growth including nitrogen and phosphorus. Nitrogen is the important nutrient for plant growth, especially as a building block for chlorophyll, enzymes, and other compounds. Maize fertilized with N turned out to have greater and more root development at the beginning of the season due to an increase in leaf area and more assimilation results for root growth (Franklin et al., 2008). The use of nano zeolite yielded the best results (Figure 5)

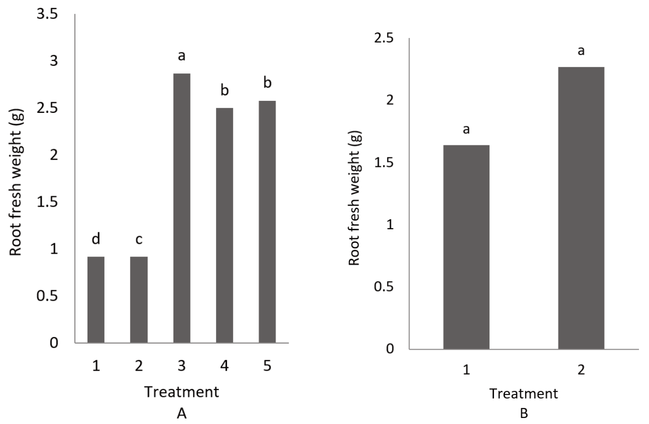


Figure 7. Root dry weight corn plan
Remarks: A = 1 (control), 2 (100 kg.ha^{-1}), 3 (200 kg.ha^{-1}), 4 (300 kg.ha^{-1}), 5 (400 kg.ha^{-1}) and B =1 (nano cow bone) and 2 (nano zeolit).

because zeolite contains a cavity that corresponds to the size of the ammonium ion, resulting in a high ammonium adsorption capacity. The use of zeolite as a zeolite-coated urea coating with a concentration of 10% gave the highest cob weight and cob length (Aina and Jumadi, 2018).

Root fresh and dry weight

Root growth functions as an absorber of water and nutrients and as a respiratory organ in the soil. Root fresh weight shows the number of roots produced by plants during growth to absorb nutrients and water before the water content in the root tissue decreases. Meanwhile, root dry weight shows the amount of biomass formed in the roots, influenced by the volume and number of the roots. The treatment of 200 kg. ha^{-1} nano zeolite led to the highest value compared to other treatments (Figure 6 and 7). The effect of nano zeolite as a coating containing nutrients to avoid being discharged directly into the environment is assumed to be the cause. Zeolite is used as a coating material due to its high cation exchange properties (Dubey and Mailapali, 2019). The fresh weight of maize roots showed the consistent effect with the fresh weight of maize shoots. The higher root fresh weight, the more optimum the absorption of nutrients. Root fresh weight can be used to determine how much nutrient and water can be absorbed by plants. Meanwhile, root dry weight is related to the ability of the root to absorb water and nutrients. This availability will be able to maximize plant growth and increase plant weight, especially the roots. The amount of water absorbed by the roots is then translocated to all plant organs, enabling plants to develop properly due to sufficient water. The dry weight reflects the nutritional status of plants, which in turn is related to nutrient availability and uptake. The use of nano zeolite as a slow-release fertilizer can maintain the availability of fertilizer. States that slow-release fertilizer is a mechanism for releasing nutrients gradually based on the pattern of nutrient absorption by plants which allow for optimal fertilizer absorption (Rugayah et al., 2019). When fertilizers are used, plants can only absorb around 40–70% nitrogen, 80–90% phosphorus, and 50–70% potassium, one of which can be overcome by using slow-release fertilizers (Novan and Dina, 2017).

CONCLUSIONS

The effectiveness of N coating with nano zeolite showed the best results as a slow-release fertilizer on N uptake compared to nano bovine bone. The optimum dose of N fertilization was 200 kg.ha^{-1} with nano zeolite coating which could increase the growth of corn plants by producing the highest plant height (167.17 cm) and N uptake of 1.6 g/plant.

ACKNOWLEDGMENTS

Authors are highly grateful to the Faculty of Agriculture, Universitas Gadjah Mada and Universitas Muhammadiyah Yogyakarta for providing facilities.

REFERENCES

Adviany, I., dan Maulana, D.D. (2019). Pengaruh pupuk organik dan jarak tanam terhadap c-organik, populasi jamur tanah dan bobot kering akar serta hasil padi sawah pada inceptisols jatinagor, Sumedang. *Agrotechnology Research Journal*, 3(1), pp. 28–35.

Aina, N., and Jumadi, O. (2018). Respon pertumbuhan jagung (Zea mays) dengan pemberian urea bersalut zeolit sebagai nitrogen lepas lambat. *Bionature*, 18(2), pp. 23–45.

Ariningsih, E. (2016). Prospek penerapan teknologi nano dalam pertanian dan pengolahan pangan di Indonesia. *In Forum Penelitian Agro Ekonomi*, 34(1), pp. 1–20.

Balai Penelitian Tanah. (2009). Petunjuk Teknis Analisis Kimia Tanah, Tanaman, Air, dan Pupuk. *2st ed. Bogor: Balai Penelitian Tanah*, pp. 211.

Bhaskoro, A.W., Kusumarini, N., dan Syekhfani, S. (2015). Efisiensi pemupukan nitrogen tanaman sawi pada inceptisol melalui aplikasi zeolit alam. *Jurnal Tanah dan Sumberdaya Lahan*, 2(2), pp. 219–226.

Damanik, M.M.B., Hasibuan, B.E., Fauzi, S., dan Hanum, H. (2011). Kesuburan tanah dan pemupukan. *Fakultas Pertanian. 2st ed. Medan: Universitas Sumatera Utara Press*, pp. 40.

Darlita, RR., Joy., Benny., Sudirja., and Rija. (2017). Analysis Of Severa L Chemical Properties Of Soil On Increasing Oil Palm Production On Soil, Sand In Selangkun Oil Palm Plantations. *Jurnal Agriculture*, 28(1), pp. 15–20.

Dubey., Alpna., Mailapalli., Damodhara., and Rao. (2019). Zeolite coated urea fertilizer using different binders: fabrication, material properties and nitrogen release studies. *Environmental Technology & Innovation*, 16(1), pp. 100–452.

Estiaty, L.M. (2015). Synthesis And Characterization Of Zeolite-Tio2 From Modified Natural Zeolite. *Jurnal Teknologi Mineral Dan Batubara*, 11(3), pp. 181–190.

Fitriatin, B.N. (2021). Serapan nitrogen dan fosfor serta hasil jagung yang dipengaruhi oleh teknik aplikasi pupuk hayati pada Inceptisols. *Kultivasi*, pp. 20(3).

Franklin, K. (2008). Shade avoidance. *New Phytol*. 170(1), pp. 930–944.

Ginting, A.B., Anggraini, D., dan Indaryati, S. (2013). Karakterisasi komposisi kimia, luas permukaan pori dan sifat termal dari zeolit bayah, tasikmalaya, dan lampung. *Jurnal Teknologi Bahan Nuklir*, 3(1), pp. 151–159.

Gunawan, G., Wijayanto, N., dan Budi, S.W. (2019). Karakteristik sifat kimia tanah dan status kesuburan tanah pada agroforestri tanaman sayuran berbasis Eucalyptus Sp. *Jurnal Silvikultur Tropika*, 10(2), pp. 63–69.

Hanafiah, A.S., Sabrina, T., dan Guchi, H. (2009). Biologi dan Ekologi Tanah. Universitas Sumatera Utara. Medan, pp. 184.

Haris, A., Fadli, A., and Yenti, S.R. (2016). Sintesis Hidroksiapatit dari Limbah Tulang Sapi menggunakan Metode Presipitasi dengan Variasi Rasio Ca/P dan Konsentrasi H_3PO_4. *Jom Fteknik*, 3(2), pp. 1–10.

Hartatik, W., Mardliyati, E., Wibowo, H., Sukarto, A., dan Yusron, Y. (2020). Formulasi dan pola kelarutan N pupuk urea-zeolit lepas lambat. *Jurnal Tanah dan Iklim*, 44(1), pp. 61–70.

Juarsah, I. (2016). Pemanfaatan zeolit dan dolomit sebagai pembenah untuk meningkatkan efisiensi pemupukan pada lahan sawah. *Jurnal Agro*, 3(1), pp. 10–19.

Khan, I., Saeed, K., and Khan, I. (2019). Nanoparticles: Properties, applications and toxicities. *Arabian Journal of Chemistry*, 12(7), pp. 908–931.

Kottegoda, N., Sandaruwan, C., Priyadarshana, G., Siriwardhana, A., Rathnayake, U.A., Berugoda Arachchige, D.M., and Amaratunga, G.A. (2017). Urea-Hydroxyapatite Nanohybrids For Slow Release Of Nitrogen. *ACS Nano Publications*, 11(2), pp. 1214–1221.

Kubo, S., Uraki, Y., and Sano, Y. (2003). Catalytic Graphitization of Hardwood Acetic Acid Lignin With Nickel Acetate. *Journal of Wood Science*, 49(2), pp. 188–192.

Lateef, A., Nazir, R., Jamil, N., Alam, S., Shah, R., Khan, M.N., and Saleem, M. (2016). Synthesis And Characterization Of Zeolite Based Nano-Composite: An Environment Friendly Slow Release Fertilizer. *Microporous and Mesoporous Materials*, 232, pp. 174–183.

Lingga, P., dan Marsono. (2008). Petunjuk Penggunaan Pupuk. Penebar Swadaya. Jakarta, pp. 140–150.

Manikandan, A., and Subramanian, K.S. (2014). Fabrication And Characterisation Of Nanoporous Zeolite Based N Fertilizer. *African Journal of Agricultural Research*, 9(2), pp. 276–284.

Mujahid, A., Sudiarso, S., dan Aini, N. (2017). Uji aplikasi pupuk berteknologi nano pada budidaya tanaman bayam merah (*Alternanthera amoena* Voss.). *Jurnal Produksi Tanaman*, 5(3), pp. 539–541.

Nainggolan, G.D., Suwardi., and Darmawan. (2009).

Pola pelepasan nitrogen dari pupuk tersedia lambat (Slow Release Fertilizer) urea - zeolit - asam humat. *Journal Zeolit Indonesia*, 8(2), pp. 89–96.

Nimmo, J.R. (2005). Porosity and Pore-Size Distribution. *Encyclopedia of Soils in the Environment*. 3(1), pp. 295–303.

Novan, A., and Dina, K.M. (2017). Kajian daya serap air (Sweling) pupuk urea slow release fertilizer (srf) menggunakan matriks kitosan-zeolit. UNESA *Journal of Chemistry*, 6(1), pp. 91–92.

Ooi, C.Y., Hamdi, M., and Ramesh, S. (2007). Properties of Hydroxyapatite Produced By Annealing Of Bovine Bone. *Ceramics international*, 33(7), pp. 1171–1177.

Pakpahan, S.I.A., Ilyas, I., dan Fikrinda, F. (2018). Pengaruh Rhizobium dan urin manusia terhadap perubahan sifat biologi dan kimia tanah di rezosfer kedelai pada inceptisol. *Jurnal Ilmiah Mahasiswa Pertanian*, 3(3), pp. 234–242.

Polat, E., Karaca, M., Demir, H., and Onus, A.N. (2004). Use of Natural Zeolite (Clinoptilolite) In Agriculture. *Journal of Fruit and Ornamental Plant Research*, 12(1), pp. 183–189.

Pratomo, S.W., Mahatmanti, F.W., dan Sulistyaningsih, T. (2017). Pemanfaatan zeolit alam teraktivasi H3PO4 sebagai adsorben ion logam Cd (II) dalam larutan. *Indonesian Journal of Chemical Science*, 6(2), pp. 161–167.

Rugayah, R., Hermida, L., Ginting, Y., dan Agustian, J. (2018). Uji aplikasi berbagai jenis pupuk urea lepas lambat (slow release urea) terhadap pertumbuhan tanaman kailan (*Brassica oleraceae* L.). *Prosiding Semnas SINTA FT UNILA Vol. 1 Tahun 2018*, 1, pp. 42–48.

Savana, R.T., dan Maharani, D.K. (2017). Pemanfaatan asam fulvat sebagai optimalizer dalam pupuk lepas lambat kitosan-zeolit. *Sains & Matematika*, 5(2), pp. 2–8.

Setyastika, U.S., dan Suntari, R. (2019). Pengaruh aplikasi bokashi terhadap dinamika ketersediaan N, P, dan S pada Inceptisol Karangploso, Malang. *Jurnal Tanah dan Sumberdaya Lahan*, 6(2), pp. 1291–1299.

Subramanian, K.S., and Tarafdar, J.C. (2011). Prospects of Nanotechnology In Indian Farming. *Indian Journal of Agricultural Science*, 81(10), pp. 887–893.

Subramanian, K.S., Manikandan, A., Thirunavukkarasu, M., and Rahale, C. S. (2015). Nano-Fertilizers For Balanced Crop Nutrition. In *Nanotechnologies In Food And Agriculture*, pp. 69–80.

Sudirja, R., Joy, B., Yuniarti, A., Sofyan, E.T., Mulyani, O., dan Mushfiroh, A. (2017). Beberapa sifat kimia tanah inceptisol dan hasil kedelai (Glycine max L.) akibat pemberian bahan amelioran. In *Prosiding Seminar Hasil Penelitian Tanaman Aneka Kacang dan Umbi*, pp. 198–205.

Sonbai, J.H.H., Prajirno, D., dan Syukur, A. (2019). Pertumbuhan dan hasil jagung pada berbagai pemberian pupuk nitrogen di lahan kering regosol. *Jurnal Ilmu Pertanian*, 16(1), pp. 77–89.

Utami, S.N.H., dan Handayani, S. (2003). Sifat kimia entisol pada sistem pertanian organik chemical properties in organic and conventional farming system. *Ilmu Pertanian*, 10(2),pp. 63–69.

Widowati, L.R., Husnain., dan Hartatik, W. (2011). Peluang Formulasi Pupuk Berteknologi Nano. *Badan Litbang Pertanian, Balai Penelitian Tanah Bogor*, pp. 307–308.